EXTREMELY SHORT DURATION HIGH INTENSITY TRAINING AS A CARDIOVASCULAR TRAINING METHOD FOR FRONT LINE POLICE OFFICERS

A thesis submitted for the degree of Master of Science by Research

by

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Declaration

Candidate’s declarations:

I, Jennifer Scally, hereby certify that this thesis submitted in partial fulfilment of the requirements for the award of Master of Science by Research, Abertay University, is wholly my own work unless otherwise referenced or acknowledged. This work has not been submitted for any other qualification at any other academic institution.

Signed [candidates signature] ...Jennifer Scally...
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I, [insert Principal Supervisors name] hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of [0000000] in Abertay University and that the candidate is qualified to submit this thesis in application for that degree.

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Certificate of Approval

I certify that this is a true and accurate version of the thesis approved by the examiners, and that all relevant ordinance regulations have been fulfilled.

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Dedication

This research is dedicated to my mother, retired Detective Constable Fionnuala Scally, a strong woman who taught me the values of hard work and perseverance. She is the inspiration for this research.

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Abstract

Purpose

The purpose of this study is to determine if extremely short duration High Intensity Training is an effective method for Police Officers to maintain their cardiovascular fitness.

Methodology

12 front line, operational Police Officers (n=5 female & n=7 male) volunteered to take part in the study (age, 42 ± 7 years; height, 173.2 ± 7.7 cm; body mass, 90.5 ± 16.6 kg; VO_{2peak}, 37.16 ± 4.65 ml kg^{-1} min^{-1}). Participants' blood pressure, critical power and VO_{2peak} were tested across two testing days on three occasions; at the beginning of the study, post 8 weeks control and post 8 weeks High Intensity Interval Training. The High Intensity Interval training protocol consisted of 6 10 second sprints on a cycle ergometer with 30 seconds recovery between sprints. Sprints were completed against a resistance of 6.5% or 7.5% of participants' body mass for females and male respectively. Participants' total peak power, average power and work done were recorded across training sessions.

Results

Following 8 weeks of High Intensity Interval Training, there was a significant increase in VO_{2peak} (p=0.004), total peak power (p=0.01), total average power (p=0.01) and total work done (p=0.01).There was no significant change in blood pressure, critical power or time to exhaustion; however there was an 8 ± 10% improvement in time to exhaustion.

Conclusions

High Intensity Interval Training is a time efficient means for Police Officers to increase their cardiovascular fitness. This study contributes to current research regarding effective High Intensity Interval Training protocols. Future research should explore the long term implications of such a training protocol for Police Officers.

Abbreviations

Geographic Information Systems	(GIS)
Heart Rate Reserve	(HRR)
Stab Resistant Body Armour	(SRBA)
Personal Protective Equipment	(PPE)
Oxygen Consumption	(VO_2)
Body Mass Index	(BMI)
Endurance Training	(ET)
Non-Communicable Diseases	(NCDs)
High Intensity Interval Training	(HIIT)
Peak Oxygen Uptake	(VO_{2peak})
Peroxisome-proliferator activated receptor γ coactivator	(PGC-1α)
Adenosine Triphosphate	(ATP)
Citrate Synthase	(CS)
Physical Activity Readiness Questionnaire	(PAR-Q)
Blood Pressure	(BP)
White Coat Hypertension	(WCHT)
Ambulatory Blood Pressure	(ABP)
Critical Power	(CP)
Respiratory Exchange Ratio	(RER)
Analysis Of Variance	(ANOVA)
Standard Deviation	(SD)
Pulse Pressure	(PP)
Aortic Pulse Wave Velocity	(PWVao)
Pulse Wave Velocity	(PWV)
Hydrogen Ion	(H^+)

1. Introduction

There has been a reduction in the physiological demands of the role of a Police Officer (Bonneau & Brown, 1995). Police Officers typically patrolled areas on foot but the introduction of vehicles has shown a reduction in foot patrols (Rawlings, 2001). This has benefits to police forces as larger areas can be covered in shorter periods of time but means that Police Officers are spending more time physically inactive (Knox & McDonald, 2001). Officers typically spend 5 or 6 hours of their shift sitting (Birzer & Craig, 1996; Anderson, Plecas & Segger, 2001).

Despite this, Police Officers must hold a level of physical fitness in order to effectively deal with Critical Incidents (Rossomanno et al. 2012). Critical incidents are defined as incidents that pose an immediate threat to life and/or property requiring emergency police intervention (Anderson, Plecas & Segger, 2001). Where Police Officers are unable to meet the physical demands of a Critical Incident, the safety of the officer, their colleagues and the general public is endangered (Dillern et al., 2014; Crawley et al. 2015). Alongside this, Police Officers are required to wear Stab Resistant Body Armour which has been shown to increase physiological demands during Critical Incidents (Dempsey, Handcock & Rehrer, 2013).

Physical activity is also important in counteracting the negative impact that shift work has on Police Officer health (Wirtz & Nachreiner, 2012). The role of a Police Officer is insufficient in itself at maintaining fitness (Shephard & Bonneau, 2002). Therefore Police Officers must look to take part in physical activity during their leisure time in order to maintain their fitness and overall health (Lagestad & Van Den Tillaar, 2014). Police Officers frequently cite time as a barrier to participation in physical activity (Rossomanno et al. 2012).

High Intensity Interval Training has been shown to provide similar adaptations to Endurance Training in shorter periods of time (Burgomaster et al. 2005). HIIT has been shown to increase time to exhaustion, peak oxygen uptake (VO_{2peak}), anaerobic work capacity and insulin action and reduce systolic blood pressure (Burgomaster et al. 2005, Babraj et al. 2009; Nybo et al. 2010; Alves et al. 2014). It also has the added benefit of reduced injury risk, associated with a reduced workload (Jakeman, Adamson & Babraj, 2009).

The aim of the present study is to determine if extremely short duration High Intensity Training is an effective method for Police Officers to maintain or improve their cardiovascular fitness. It is hypothesised that 8 weeks of High Intensity Interval Training will result in positive physiological adaptations, similar to that of Endurance Training.

2. Literature Review

2.1 Role of a Police Officer

The fundamental aim of a police officer is to maintain peace, prevent crime and disorder and to protect life, liberty and property (Ward, 1971). Whilst the aim of a police officer remains the same, it has been suggested that there has been a reduction in the amount of physical activity required to meet the demands of the job over time (Bonneau & Brown, 1995). This is true for all police forces around the world, with task analysis showing that the occupational demands of a police officer are the same in Europe, Australia, America and Canada (Bonneau & Brown, 1995).

2.1.1 Reduction in Physical Demands of Police Officer's Role

Traditionally police officers foot patrolled large areas of cities and towns that they were assigned to known as their beat (Wain & Ariel, 2014). This was identified as a fixed-point system as there would be telephones placed along the beat that officers would be expected to reach at a given time and call the station (Wain & Ariel, 2014). Calling the station would confirm the safety of the officer and the timings of each point would be changed in order to prevent criminals from learning the routine (Wain & Ariel, 2014). The laborious nature of walking a beat was seen as unappealing to many potential recruits (Rawlings, 2001). In the 1940s, the efficiency of this system was questioned due to increases in car crime, variances in crime patterns and a shortage of police officers (Rawlings, 2001). By the late 1940s and with numbers reducing, there was an introduction of vehicles in order to cover larger areas of patrol with smaller numbers of officers (Rawlings, 2001; Wain & Ariel, 2014). By the 1960s, a combination of radio cars and on foot police officers were utilised in order to patrol beats (Rawlings, 2001). The introduction of personal radios saw the usage of vehicles on patrols increase with 60% of the United Kingdom's population covered by these unit beats by 1968 (Rawlings, 2001). Now police officers had greater control as to how they patrolled their beat, could easily reach areas in a shorter time period. This capacity to cover large areas quickly lead to the development of response policing (Wain & Ariel, 2014). The use of cars for response policing has continued to this day and instead of patrolling entire beats, geographic information systems (GIS) are used in order to determine small patches of beats known as hotspots where crime is frequently occurring (Wain & Ariel, 2014). This approach to policing has been shown to result in a 25% reduction in crime, with hotspots being patrolled for 12 – 16 minutes every 2 hours in Sacramento (Wain & Ariel, 2014).

Alongside an increased utilisation of police cars, 43% of police officers' time is spent within police stations (Knox & McDonald, 2001). This is a result of the time that it requires to process detained suspects and prepare paperwork for reports (Knox & McDonald, 2001). Arresting, processing and gathering information for a crime report regarding an accused person will take an average of 3.5 hours (Knox & McDonald, 2001). Reassurance patrols account for 17% of police time and when this does occur, only 6% of patrols are conducted on foot as officers must utilise vehicles so that they can react to response calls when necessary (Knox & McDonald, 2001).

Increased paperwork alongside reduced foot patrols means that a police officer will spend approximately 80-90% of their time completing activities that require very limited physical exertion such as sitting and standing (Anderson, Plecas & Segger, 2001). Officers frequently spend as much as 5 or 6 hours of their shift sitting (Birzer & Craig, 1996; Anderson, Plecas & Segger, 2001, Lagestad, 2011). When recording police officer heart rates across an 8 hour shift, Lönn, Lönn & Hansen (2006) found that police officers heart rate data equated to walking briskly for 8 minutes of the 8 hours. Secondments, sickness and training courses reduces the number of officers available for high visibility, reassurance patrols (Knox & McDonald, 2001). The majority of a police officer's time is spent within a vehicle or using a computer (Lönn, Lönn & Hansen, 2006). Police officers require very little strength or other physical skills for the better part of their time on duty (Bonneau & Brown, 1995; Lagestad, 2011).

2.2 Critical Incidents

2.2.1 Critical Incidents and Likely Suspects

Police officers are ultimately required to deal with periods of maximal physical activity known as critical incidents (Rossomanno et al. 2012). Critical incidents are defined as incidents that pose an immediate threat to life and/or property requiring emergency police intervention (Anderson, Plecas & Segger, 2001). Whilst intermittent, dealing with critical incidents remains an essential and critical part of the occupation which can be life threatening to both members of the public and police officers (Bonneau & Brown, 1995; Dillern et al., 2014; Crawley et al. 2015). During a critical incident, a police officer has an 89% probability of facing one or more suspects; suspects who will be violent in 50% of cases (Anderson, Plecas & Segger, 2001). Suspects in critical incidents are likely to be male, younger, taller in 36% of cases and heavier in 36% of cases than the police officers involved (Anderson, Plecas & Segger, 2001). Suspects will likely be under the influence of alcohol or drugs (Anderson, Plecas & Segger, 2001). Furthermore one study found that 79% of suspects involved in critical incidents were of average fitness or higher (Anderson, Plecas & Segger, 2001). Police officers should have levels of physical fitness higher than the public in order to allow them to effectively capture and control suspects during critical incidents (Adams et al. 2010).

2.2.2 Physiological Demands of a Critical Incident

In 54% of critical incidents, officers are required to run, accelerate, decelerate and change their direction (Anderson, Plecas & Segger, 2001). Sustained pursuit can require jumping, climbing, vaulting, evading and climbing stairs (Collingwood, Hoffman & Smith, 2004; Bonneau & Brown, 1995; Anderson, Plecas & Segger, 2001). All of these tasks have been self-reported by police officers as requiring maximal effort in an attempt to catch a fleeing suspect (Anderson, Plecas & Segger, 2001). Gaining control of resisting suspects is the most physically demanding task required of police officers within their duties (Dillern et al. 2014). Dillern et al. (2014)

have shown that police officers with higher levels of physical capacity measured as maximum and endurance upper body strength, aerobic power and explosive power are more likely to be able effectively arrest and control resisting suspects during critical incidents**.**

Subjects will resist and combat attempts made by police officers to restrain them in 57% of instances; when suspects resist and combat attempts to restrain them, this will require medium to maximum self-reported exertion in 72% of occasions (Anderson, Plecas & Segger, 2001; Dillern et al. 2014). In order to gain control of a suspect, a police officer will be required to push and pull the suspect in 93% of occasions and twist and turn and use holds in 86% of cases, with intensity of the situation being shown to be equivalent to 46-85% of heart rate reserve (HRR) (Anderson, Plecas & Segger, 2001; Anderson, Litzenberger & Plecas, 2002). Heart Rate Reserve is the variance between an individual's maximum and resting heart rates (Hayes et al. 2013). Police officers will otherwise wrestle with suspects in 57% of incidents at an intensity equivalent to 51-73% HRR (Anderson, Plecas & Segger, 2001; Anderson, Litzenberger & Plecas, 2002). When attending a motor vehicle accident, clearing debris on the roads or removing a suspect from a location following a critical incident, officers will need to lift, carry, pull, drag and push objects or persons all of which requiring self-reported maximum physical exertion (Collingwood, Hoffman & Smith, 2004; Anderson, Plecas & Segger, 2001). Research by Lönn, Lönn & Hansen (2006) found that in 60.3% of critical incidents, police officers work intensity exceeded 50% of their HRR. From task analysis, it is generally accepted that police officers require anaerobic power, aerobic capacity, strength, muscular endurance and agility (Crawley et al. 2015, Bonneau & Brown, 1995; Shephard & Bonneau, 2002; Collingwood, Hoffman & Smith, 2004).

2.3 Physiological Demands of Stab Resistant Body Armour

Police officers are required to wear stab resistant body armour (SRBA) for prolonged time periods whilst conducting their duties in order to prevent or reduce damage to vital organs caused by stabbing, damage from smaller calibre bullets and blunt force trauma (Dempsey, Handcock & Rehrer, 2013; Ricciardi et al. 2008). Police officers are also required to carry personal protective equipment (PPE) on a utility belt that assists them in conducting their duties and protecting themselves from attacks (DiVencenzo et al. 2014). Typical PPE carried includes handcuffs, baton, incapacitant spray, a torch and a two-way radio (Dempsey, Handcock & Rehrer, 2013).

Whilst there are clear safety advantages to wearing SRBA and PPE, they weigh 2.7-3.8 kg and 3.5 kg respectively (Dempsey, Handcock & Rehrer, 2013). In countries where response officers are required to carry firearms and associated ammunition, the weight of PPE is higher and typically weighs 3.62-6.8kg (DiVencenzo et al. 2014). The external weight of carrying PPE and wearing SRBA has been found to significantly increase physiological demands of physical activity and decrease mobility (Dempsey, Handcock & Rehrer, 2013; DiVencenzo et al. 2014).

Dempsey, Handcock & Rehrer (2013) found that performance of 5 minute run at 13 $km.h^{-1}$ whilst wearing SRBA and simulated PPE totalling 7.65kg resulted in an increase of 2.8 $\%VO_{2max}$ ($ml.kg^{-1}.min^{-1}$) & 6.4$\%HR_{max}$ ($b.min^{-1}$) when compared to control data. DiVencenzo et al. (2014) found that wearing 6.2-6.7 kg of SRBA and PPE during simulated conditions and 1.5m run increased VO_2 during walking, jogging and running by 7% and increased heart rate during walking, jogging and running by 5-7% when compared to tests without SRBA and PPE. Time taken to exit a car seat, turn and sprint was 16% slower when completed wearing SRBA and PPE (Dempsey, Handcock & Rehrer, 2013). Agility is affected by SRBA and PPE as police officers will have increased momentum given their additional mass requiring greater force in order to change velocity (Dempsey, Handcock & Rehrer, 2013).

Increased physiological demands of the job that are associated with wearing SRBA and PPE means that carrying this equipment has a negative effect on occupational performance during critical incidents (Dempsey, Handcock & Rehrer, 2013). In order to counteract the detrimental effect of carrying SRBA and PPE on physical capacity, police officers require increased levels of cardiovascular fitness (DiVencenzo et al. 2014).

2.4 Police Officers and Physical Fitness

2.4.1 Necessity of Physical Fitness of Police Officers

Critical incidents of all natures can take place at any moment within a shift, at any location and without forewarning (Anderson, Plecas & Segger, 2001; Lagestad, 2011). Furthermore, over a third of critical incidents took place from observations made by the police officer as opposed to being dispatched to calls made by members of the public (Anderson, Plecas & Segger, 2001). Due to their unpredictable nature, all police officers must be able to respond and adapt from periods of low intensity activity to high intensity activity (Crawley et al. 2015).
If police officers are unable to handle the physical demands, the safety of the public is compromised and the duties of a police officer have not been satisfied (Bonneau & Brown, 1995). These duties remain the same regardless of the age or sex of the police officer and as such ability to deal with critical incidents is a performance indicator of occupational efficiency (Crawley et al. 2015). When evaluating the highest performing police officers, one study found that all of these officers regularly took part in regular physical activity (Lagestad, 2011). Police officers surveyed in Texas shows that whilst they believed dealing with critical incidents to be less important than other occupational requirements; that it remains critical to the role of a police officer (Bissett, Bissett & Snell, 2012). While the use of physical force to gain control of resisting suspects occurs in only 5% of encounters, it can account for 40% of occupational accidents (Dillern et al. 2014). Poor levels of fitness can lead to increased injury rates, permanent injury, reduced occupational performance and increased employee turnover (Anderson, Plecas & Segger, 2001). As arresting suspects is an occupational requirement being unable to do so can reduce the occupational effectiveness of the officer and the number of police officers who can

ultimately meet the duties of the job. Hiring police officers without the physical fitness to do so could leave police forces liable in legal proceedings (Lonsway, 2003).

2.4.2 Police Officer Fitness Testing

Whilst there is a consensus that police officers require a certain level of physical fitness, there is very little agreement regarding an exact testing protocol for potential police recruits (Anderson, Plecas & Segger, 2001; Dillern et al. 2014). There are a variety of fitness tests utilised by police forces despite the fact that the physical demands of the job across forces are the same (Kuruganti & Rickards, 2004). In the earlier parts of the century, police forces utilised height and weight standards as an indicator of physical performance (Bonneau & Brown, 1995). As time has progressed these standards have been found to be discriminatory and fitness tests are frequently used in order to determine the fitness of potential recruits and probationers (Bonneau & Brown, 1995; Anderson, Plecas & Segger, 2001; Bissett, Bissett & Snell, 2012).

Many of the fitness tests that have since been established by police forces have been found to be discriminatory and have been removed from use (Anderson, Plecas & Segger, 2001; Bissett, Bissett & Snell, 2012). As the nature of a fitness test is to screen out participants with unsatisfactory physical capacity, the use of a fitness test is likely to have an adverse impact on certain demographics such as women, older recruits and applicants with a physical impairment (Shephard & Bonneau, 2002). In order to effectively implement a fitness test that passes legislature, fitness tests must prove that they are directly correlated to occupational performance (Shephard & Bonneau, 2002; Bissett, Bissett & Snell, 2012; Anderson, Plecas & Segger, 2001). In other words, that failing the fitness test equates to recruits being unable to conduct their duties as a police officer (Shephard & Bonneau, 2002; Bissett, Bissett & Snell, 2012; Anderson, Plecas & Segger, 2001). Where forces implement fitness testing protocols, they are infrequently re-evaluated for validity and remain in place for extended periods of time (Kuruganti & Rickards, 2004).

Determining physical fitness of police officers can be conducted through aerobic fitness assessments or job simulation tasks (Jamnik, Gumienak & Gledhill, 2013). Job simulation tasks enable the measurement of physical components such as muscular endurance, muscular strength, power, agility, flexibility and balance under realistic conditions (Jamnik, Gumienak & Gledhill, 2013). Job simulation tasks are unable to estimate aerobic fitness required in critical incidents and as such discrete aerobic fitness tests are often utilised alongside job task simulation tests or are independently measured in hybrid tests (Jamnik, Gumienak & Gledhill, 2013). In England, Wales & Scotland, fitness for duty is determined using a 15 metre bleep (multi stage fitness) test (College of Policing, 2014; Police Scotland, 2017). Police officers are required to obtain level 5 stage 4 on the test, equating to an aerobic capacity of 31 mL^{-1} min^{-1} (Andrew et al. 2009).

2.4.3 Maintenance of Fitness

Whilst there is a large emphasis placed on determining the physical fitness of recruits, there is very little emphasis placed on the physical fitness of serving officers (Anderson, Plecas & Segger, 2001). An international survey of nearly 3000 police forces found that whilst 81% had some entry standard of physical fitness, that only 16% held their incumbents to a similar standard of physical fitness (Shephard & Bonneau, 2002). The role, duties and physical demands required of a police officer at a specific rank does not change with years of service (Bonneau & Brown, 1995). If fitness tests are implemented by forces for recruits and probationers, tests which are supposedly inherent to occupational performance then it must be assumed that they are to be required of incumbent police officers (Anderson, Plecas & Segger, 2001). It is difficult for forces to defend fitness testing standards when they are not upheld by all serving police officers in the same role (Bonneau & Brown, 1995). Fitness testing recruits and probationers does not ensure that police officers will maintain their fitness in following years of service (Bissett, Bissett & Snell, 2012).

Due to the primarily sedentary nature of the job, the job in itself is insufficient in maintaining physical fitness (Shephard & Bonneau, 2002). Physical fitness and overall health of police officers has found to reduce with years of service (Bonneau & Brown, 1995; Bissett, Bissett & Snell, 2012).

2.4.4 Reduction in Health & Sickness Absence

Finnish police officers were found to significantly reduce their levels of physical activity after three years of police service and had gained 0.5kg in body mass (Lagestad & Van Den Tillaar, 2014). A 15 year follow up study by Sorensen et al (2000) found that police officer's aerobic fitness had been maintained, muscular strength had reduced and the number of overweight officers jumped from 29% to 51%. Health checks on Metropolitan Police officers & staff found that 50% and 75% of women and men respectively were classified as overweight, obese or morbidly obese (Winsor, 2012). In the Netherlands, male police officers aged 50 and above were found to be twice as likely to be obese in comparison to their non-police counterparts (Houtman et al. 2005). Increased body fat percentages have been shown to be inversely correlated to overall physical fitness in police officers (Violanti et al. 2016).

Alongside correlations regarding high body max index (BMI) and reduced overall fitness, individuals with higher BMIs are more likely to experience reduced health (Fekedulegn et al. 2013). As an emergency service, a large proportion of police officers undertake shift work in order to ensure a 24 hour service (Wirtz & Nachreiner, 2012). Wirtz & Nachreiner (2012) found that prolonged exposure to shift work in police officers, irrespective of age has a significant impact on overall health and fitness for duty. Working shift patterns disrupts the body's circadian rhythms and has a detrimental physiological impact on sleeping, working and eating cycles (Harrington, 2001). Variances in circadian rhythms alongside variances in social support, stress, diet and exercise attribute to a 40% increased risk of cardiovascular disease (CVD) in shift workers (Bøggild & Knutsson, 1999). Shift workers are more likely to experience hypertension, angina pectoris and myocardial infarctions (Harrington, 2001). Police officers exposed to shift work have an increased level of sickness absence as opposed to those who only work during the day (Fekedulegn et al. 2013). In England's police forces, over 1.5 million days of work were lost due to sickness absence in 2000-2001 (Paton, 2004). This equates to 12.2 days per officer whereas the average number of sick days in the same year for the public and private sectors was 10.2 and 7.2 days per employee respectively (Paton, 2004).

Police officers with abdominal obesity were 2.3 times more likely to take three days or more of sickness absence consecutively in comparison to their non-obese colleagues (Fekedulegn et al. 2013). In this research, abdominal obesity was defined as a waist circumference of 88cm or 102cm or more for women and men (Fekedulegn et al. 2013). It is hypothesised that police officers with increased levels of obesity are more susceptible to non-communicable diseases and require more time in order to recover from sickness (Fekedulegn et al. 2013). With normal pension ages for police officers increasing, police officers will be faced with an increased exposure to shift work and reduced fitness for duty (Wirtz & Nachreiner, 2012). Therefore police forces must either work to ensure fitness for duty in their officers or place further demand on younger service officers to partake in shift work (Wirtz & Nachreiner, 2012). This could have even more of a negative impact by increasing the work load on a certain demographic with less experience (Wirtz & Nachreiner, 2012).

2.4.5 Maintenance of Fitness

There are many debates regarding with whom the responsibility of fitness duty lies; in particular the chief constable of the force or the police officer themselves (Winsor, 2012). Regardless, police officers who are unfit for duty ultimately compromise the safety of the general public, fellow officers and themselves (Anderson, Plecas & Segger, 2001). In order to maintain physical fitness, police officers must integrate physical activity into their daily lives whilst at work or in their leisure time (Lagestad & Van Den Tillaar, 2014). However, police officers frequently cite feelings of exhaustion and insufficient time as barriers to participation in physical activity (Rossomanno et al. 2012). Shift work also presents increased barriers to physical activity, as working evenings and weekends can prevent participation in traditional sporting activities that are tailored towards traditional 9-5 working hours (Harrington, 2001).

2.5 High Intensity Interval Training

2.5.1 High Intensity Interval Training versus Endurance Training

It is widely accepted that traditional Endurance Training (ET) is effective at increasing oxidative metabolism, cardiovascular fitness and glucose tolerance and reducing hypertension and the risk of suffering from non-communicable diseases (NCDs) such as cardiovascular disease (Booth et al. 2002; Burgomaster et al. 2008; Nybo et al. 2010). Whilst ET is an effective means of maintaining health, it can be time consuming (Jakeman, Adamson & Babraj, 2009). The minimal amount of physical activity recommended is 150 minutes of moderate intensity or 60 minutes of vigorous intensity exercise (Donnelly et al. 2009; Haskell et al. 2007). Members of the public, including police officers are seeking the most time efficient means of exercise possible in order to maintain their health (Booth et al. 2000). High Intensity Interval Training (HIIT) provides a suitable alternative to ET with increasing evidence demonstrating that HIIT can provide similar physiological adaptions to ET in shorter work periods (Burgomaster et al. 2005). HIIT is defined as short bursts of maximal exercise alternated with rest or periods of low intensity exercise (Gibala et al. 2012). HIIT has been shown to increase time to exhaustion, maximal oxygen uptake (VO_{2MAX}), anaerobic work capacity, insulin action, cognitive function and mood and reduce systolic blood pressure (Burgomaster et al. 2005, Babraj et al. 2009; Nybo et al. 2010; Alves et al. 2014).

Inducing physiological adaptions similar to ET in a shorter time period permits a reduction in overall workload and risk of injury from training (Jakeman, Adamson & Babraj, 2009). Athletes typically obtain injuries due to overtraining or can experience reduced aerobic capacity and maximal heart rate where the workload placed on them is too high (Halson & Jeukendrup, 2004). In addition this this, exercise interventions conducted on a cycle ergometer including HIIT do not require weight bearing, decreasing injury risk (Kravitz, Chantal & Vella, 2014). The importance of overtraining and associated injury risk or reduction in performance has been highlighted for athletes however the same may apply to police officers who must be physically ready to deal with critical incidents at any point whilst on shift (Jakeman, Adamson & Babraj, 2009).

2.5.2 Adaptations to High Intensity Interval Training

Mitochondrial biogenesis is strongly regulated by coactivator peroxisome-proliferator activated receptor γ coactivator (PGC-1α) which activates metabolic and mitochondrial adaptations in skeletal muscle (Wu et al. 1999). Mitochondrial biogenesis is where cells with mitochondria grow or increase in quantity, allowing cells to create more adenosine triphosphate (ATP) (Russell et al. 2014). Increasing the rate of ATP production increases substrate metabolism; leading to improved oxidation of fax and a correlated reduction in carbohydrate metabolism (MacInnis & Gibala, 2017).This means at a given workload; there will be a reduction in lactate production and anaerobic glycogenosis resulting in enhanced submaximal capacity (Little et al. 2011; MacInnis & Gibala, 2017).

Endurance training has been evidenced to elicit increases in PGC- 1α and associated skeletal muscle mitochondrial biogenesis (Little et al. 2011; MacInnis et al. 2017). It has been demonstrated that individuals have lower PGC-1α expression following periods of inactivity (Timmons et al. 2006). HIIT has been evidenced to increase PGC- 1α mRNA 3 hours post exercise comparable with PGC- 1α mRNA following continuous training (Gibala et al. 2012). This supports the theory that HIIT increases mitochondrial biogenesis and skeletal muscle oxidative capacity (Little et al. 2011).

Further research has demonstrated that HIIT can elicit superior changes in PGC- 1α mRNA 3 hours post exercise than following low intensity exercise bouts (Egan et al. 2010). In a study by MacInnis et al (2017), participants acted as their own controls with one leg cycling utilised to compare HIIT and moderate intensity exercise. At matched duration and work, citrate synthase (CS) activity was significantly higher in the HIIT leg than in the leg that completed moderate intensity exercise (MacInnis et al. 2017). CS is an enzyme involved in the first stage of the TCA cycle and a mitochondrial enzyme whose increased presence indicates an increased mitochondrial content (MacInnis & Gibala, 2017) Further, HIIT has been shown to increase COXIV content and training after 2 weeks (Burgomaster 2005). COXIV is an electron transport chain enzyme whose increase also reflects greater mitochondrial content (MacInnis & Gibala, 2017).

Insulin sensitivity has been found to increase with only 6 sessions of HIIT in overweight and obese men (Whyte, Gill & Cathcart, 2010). Research by Babraj et al (2009) found that 2 weeks of HIIT enhanced insulin action in young males and that this effect lasted for at least an additional 3 days post final training session. This is suggested to be due to an increase in GLUT4, the most highly expressed transporter of glucose in the skeletal muscle (Babraj et al. 2009). 6 weeks of HIIT has been evidenced to increase GLUT4 concentrations by 13 – 35% with the capacity to sustain this across the training intervention (Burgomaster et al. 2005).

Calcium ions (Ca^{2+}) activate muscle contraction and are typically stored in the sarcoplasmic reticulum (SR) (Harmer et al. 2014). Research by Matsunaga et al (2007) has demonstrated that a single bout of HIIT increased sarcoplasmic reticulum (SR) Ca^{2+} uptake in resting skeletal muscle by 12.4%. Neuromuscular fatigue is induced by sustained skeletal muscle contractions and improved SR Ca^{2+} uptake can reduce the rate at which this fatigue is onset (Billaut, 2011). This implies that HIIT could delay the onset of neuromuscular fatigue following adaptations to training (Matsunaga et al. 2007).

2.5.3 High Intensity Interval Training Protocols

HIIT can induce variably sized physiological adaptions, dependent on the nature of the protocol and its intensity, work:rest ratio, number of sprints and duration of sprints (Burgomaster et al. 2005, Gibala et al. 2012). The most commonly utilised HIIT protocol consists of between 4 and 6 30 second sprints interspersed with 4 minute recovery between sprints on a cycle ergometer (Gibala et al. 2006, Burgomaster et al. 2008; Gibala et al. 2012). This training protocol has been found to elicit increases in aerobic capacity and anaerobic capacity similar to 60 to 90 minutes of ET completed at 65% to 80% of VO_{2peak} (Gibala et al. 2006; Burgomaster et al. 2008; Gibala et al. 2012). This workload equates to 2 to 3 minutes of high intensity exercise, a work:rest ratio of 1:8 and was conducted against 7.5% of participant's body mass as utilised by the Wingate Test (Gibala et al. 2006, Burgomaster et al. 2008; Gibala et al. 2012).

Whilst the exercise time may be reduced to 2 to 3 minutes, the aforementioned protocol would require approximately 30 minutes when recovery periods, warm up and cool down time are accounted for (Gibala et al. 2012). Such protocols remove time efficiency and any associated benefits of a shorter work time for individuals whose primary barrier to exercise is time (Yamagishi & Babraj, 2017). Peak power output during the first 10 seconds of the sprint is critical in inducing physiological changes and research by Hazell et al (2010) highlighted similar adaptations aerobic capacity and anaerobic performance during HIIT sprints lasting 10 and 30 seconds. Hazell et al (2010) utilised 30 second sprints with 4 minutes recovery and 10 second sprints with either 4 or 2 minutes recovery. This equated to work:rest ratios of 1:8, 1:24 and 1:12 respectively meaning sprint time cannot be directly equated. This research into sprint times was improved upon by Yamagishi & Babraj (2017) who compared 30 second sprints with 4 minutes recovery alongside 15 second sprints with 2 minutes recovery; maintaining a 1:8 ratio. This research evidenced that in half of the protocol time, the same adaptations in anaerobic and aerobic capacity could be maintained that have been equated to ET (Yamagishi & Babraj, 2017).

2.5.4 Potential Benefit of High Intensity Interval Training to Police Officers

There is a clear requirement for Police Officers to maintain their cardiovascular fitness in spite of growing workplace inactivity and barriers to exercise (Anderson, Plecas & Segger, 2001). The benefits of ET are clear however continuous training requires a large time commitment which has been identified as a barrier to Police Officer participation (Rossomanno et al. 2012).). Current literature suggests that HIIT can provide similar anaerobic and aerobic adaptations to ET but with a much lower training time commitment (Burgomaster, 2005; Gibala et al 2012). Studies have shown the effectiveness of HIIT protocols that take approximately 15 minute sessions with high intensity exercise required for only 90 seconds of the 15 minutes. As Police Officers have a requirement to maintain their aerobic and anaerobic capacity but struggle to find the time to exercise, HIIT could be a time efficient method by which Police Officers maintain their cardiovascular fitness. One researcher has utilised HIIT with a police officer; using HIIT as means of cardiac rehabilitation but none have demonstrated its use as an endurance training method (Adams & Bebarie, 2013). Therefore the aim of the present study is to determine the effectiveness of HIIT in maintaining and/or improving Police Officer’s cardiovascular fitness.

3. Methodology

3.1 Study Approval

The study protocol was approved by the School of Health and Social Sciences Ethics Committee at Abertay University. The study was conducted following the regulations contained within the Declaration of Helsinki. Police Scotland provided permission for officers within D Division (Tayside) to take part in the study given their participation was independent from their work hours.

3.2 Participants

12 front line, operational police officers (n=5 female and n=7 male) volunteered to take part in the present study (Table 1); following an advertisement posted in Police Scotland's divisional online bulletin (Appendix A). The participants were provided with verbal and written information (Appendix B) regarding the study before providing informed consent and completing an associated form (Appendix C). To be eligible for the study, police officers had to be operational, not currently taking part in HIIT and be free from injury in their lower extremities in the last 6 months (Jakeman, Adamson & Babraj, 2012). This information was reaffirmed by the completion of a Participant Information Form (Appendix D). Participants were informed that they were free to leave the study at any point without reason and were screened for chronic health conditions utilising a Physical Activity Readiness Questionnaire (PAR-Q) (Appendix E). All participants were asked to take part in consistent levels of physical activity throughout the entirety of the study and were educated regarding the impact that alterations to their levels of physical activity, out with of the HIIT program, could impact the results of the study (Babraj et al. 2009). Participants were asked to refrain from taking part in any strenuous physical activity within 48 hours prior to physiological testing (Nybo et al. 2010).

One subject chose to leave the present study, one subject took part in a 24 hour long physical activity event within 48 hours prior to physiological testing and one subject failed maintain their typical physical activity practice in one of the periods. As such, 3 participants were ineligible for the present study and their data was not included in data analysis. Data analysis included 9 participants (n=4 female and n=5 male). Table 1 summarises the characteristic data of participants included in data analysis.

Table 1: Subject Baseline Characteristics

	All Participants	Participants Included in Data Analysis
Age (years)	42 ± 7	42 ± 7
Height (cm)	173.2 ± 7.7	173.3 ± 7.8
Body Mass (kg)	90.5 ± 16.6	90.7 ± 18.0
VO_{2peak} (ml kg^{-1} min^{-1})	37.16 ± 4.65	36.44 ± 5.15

Values are mean ± S.D.

3.3 Study Design

Participants acted as their own controls in order to account for biological variation caused by individualised responses to training (MacInnis et al. 2017). Individual variability can impact on the study's statistical power (Yamagishi & Babraj, 2017). Each participant performed three rounds of physiological testing and conducted the control period prior to the HIIT period to prevent any trained effects. Table 2 highlights the study design in its entirety. Each round of physiological testing required attendance at the laboratory on two different testing days in the same week. The time of each testing day remained consistent throughout the study and where participants were unable to match the exact timing, testing was within 2 hours of this time (Jakeman, Adamson & Babraj, 2012).

Table 2: Study Design

Week	Protocol		Testing Phase
Week 1	Testing Day 1	Testing Day 2	pre1
Weeks 2 - 9	Control Period		
Week 10	Repeat Testing Day 1	Repeat Testing Day 2	pre2
Weeks 11 - 18	HIIT Period		
Week 19	Repeat Testing Day 1	Repeat Testing Day 2	post

3.4 Physiological & Psychological Testing

3.4.1 Height

Participants' height was measured at the beginning of the study at Testing Day 1 utilising a standiometer following the removal of their socks and footwear (seca 264, seca, Hamburg, Germany) (Yamagishi & Babraj, 2017).

3.4.2 Body Mass

Subject's body mass was measured utilising a body composition analyser following the removal of subject's socks and footwear (SC-330ST Tanita Body Composition Analyser, Tanita Europe BV, Amsterdam, the Netherlands) (Yamagishi & Babraj, 2017).

3.4.3 Blood Pressure

In clinical environments such as laboratories, participants can experience atypical and elevated blood pressure (BP) readings known as white coat hypertension (WCHT) (Ohkubo et al. 2005). This can prevent accurate readings from being obtained for participants within medical and scientific environments (Ohkubo et al. 2005). Ambulatory blood pressure (ABP) measurements, which are taken over an extended period of time such as 24 hours can counteract this phenomenon and permit professionals to obtain more accurate results by reducing the effect of WCHT (Wallace & Fahey, 2011). Wallace & Fahey (2011) demonstrated that readings over 30 minutes can remove the effect of WCHT and saw a reduction in systolic and diastolic BP readings by 7.6 – 9.1 mmHg and 1.5 – 3.4 mmHg respectively. This was reaffirmed by Bos & Buis (2017) who found that taking a BP reading every 5 minutes for 30 minutes resulted in lower systolic and diastolic readings.

Participants' BP was measured over 30 minutes, with BP readings taken every 5 minutes using an ABP monitor (BPLab Standard, BPLab, Nizhny Novgorod, Russia). Blood pressure readings were recorded utilising Vasotens software which utilised an algorithm to determine aortic pulse wave velocity as described by Ageenkova & Purygina (2011) (BPLab, Nizhny Novgorod, Russia). The software produced a collated report including data on resting heart rate, pulse pressure and aortic pulse wave velocity.

3.4.4 Critical Power

Following a 2 minute warm up on a cycle ergometer at 60 rpm, Critical Power (CP) was determined utilising a single 3 minute cycling test conducted against a resistance equalling 4.5% of the subject's body mass (Monark 894E, Monark, Varberg, Sweden). During the test, participants were asked to cycle at their maximal pace and were provided with no indicator regarding testing time in order to prevent self-pacing (Constantini, Sabapathy & Cross, 2014). This 3 minute test has been shown to be a valid and reliable indicator of CP, where CP is measured as the average power output obtained by the subject during the last 30 seconds of cycling test (Bergstrom et al. 2012). One participant's CP results were invalidated for not following the procedures of the test and were removed from data analysis.

3.4.5 VO_{2peak} Test

Following a 2 minute warm up on a cycle ergometer at 60 rpm, participants were asked to perform an incremental cycling test to exhaustion in order to measure VO_{2peak} and time to exhaustion (Monark 894E, Monark, Varberg, Sweden) (Heyward, 2000). Criteria for maximal effort during testing was set as a Respiratory Exchange Ratio (RER) of 1.20 or higher (Edvardsen, Hem & Anderssen, 2014). This criteria is important in enabling researchers to accurately interpret tests as maximal and reduce researcher error (Edvardsen, Hem & Anderssen, 2014). Average RER scores for each time period were pre1 1.25 ± 0.11, pre2 1.29 ± 0.12 and post 1.21 ± 0.14.

Participants were asked to cycle at 60 rpm throughout the duration of the test but were unable to see any other data typically displayed on the ergometer. All clocks and watches were removed from subject's sight. Testing started with 1kg of resistance on the ergometer and was increased by 0.5kg per minute. Participants were unaware of the timing of increments in resistance. The test was terminated when participants could no longer cycle at 60 rpm and time to exhaustion was calculated by measuring test time on a stop clock (Quantum 5500, EA Combs Limited, London, United Kingdom). Pulmonary gas exchange was measured using an online gas collection system and VO_{2peak} was calculated using 20 second averages (Metalyzer 3B, Cortex, Leipzig, Germany).

3.4.6 Schedule of Testing

The same schedule of testing was utilised throughout the duration of the study (Table 3). Physiological tests were placed after measurement of blood pressure in order to counteract any impact that exhaustive exercise could have on results.

Table 3: Schedule of Testing

Testing Day 1	Testing Day 2
Body Mass	VO_{2peak} Test
Blood Pressure	
Critical Power	

3.5 High Intensity Interval Training Protocol

The most commonly utilised HIIT protocol consists of between 4 and 6 30 second sprints interspersed with 4 minute recovery between sprints on a cycle ergometer (Gibala et al. 2006, Burgomaster et al. 2008; Gibala et al. 2012). Whilst the exercise time may be reduced to 2 to 3 minutes, the aforementioned protocol would require approximately 30 minutes when recovery periods, warm up and cool down time are accounted for (Gibala et al. 2012). Such protocols remove time efficiency and any associated benefits of a shorter work time for individuals whose primary barrier to exercise is time (Yamagishi & Babraj, 2017). Peak power output during the first 10 seconds of the sprint is critical in inducing physiological changes and research by Hazell et al (2010) highlighted similar adaptations aerobic capacity and anaerobic performance during HIIT sprints lasting 10 and 30 seconds.

This research into sprint times was improved upon by Yamagishi & Babraj (2017) who compared 30 second sprints with 4 minutes recovery alongside 15 second sprints with 2 minutes recovery; maintaining a 1:8 ratio. This research evidenced that in half of the protocol time, the same adaptations in anaerobic and aerobic capacity could be maintained that have been equated to ET (Yamagishi & Babraj, 2017).

The HIIT protocol utilised was similar to that utilised by Kavaliauskas, Aspe & Babraj (2015) but with variances in % resistances by sex as utilised by Yamagishi & Babraj (2017). This protocol was chosen due to its time efficiency as Police Officers frequently cite time as a barrier to exercise (Rossomanno et al. 2012). The protocol utilised by Kavaliauskas, Aspe & Babraj (2015) was found to improve 3km time trial performance in long distance runners following a 2 week HIIT protocol. Participants completed 16 sessions of HIIT over 8 weeks, averaging 2 sessions a week. There was at least 24 hours between each HIIT session.

Warm up for each training session was a 2 minute at 60 rpm on a cycle ergometer (Monark 894E, Monark, Varberg, Sweden). Each training session on the ergometer consisted of 6 10 second maximal sprints with 30 seconds rest in between. The resistance on the ergometer was 6.5% and 7.5% of subject's body mass for females and males respectively. The researcher directed participants when to sprint, when the rest periods had started and provided encouragement during sprints. During rest phases, participants remained on the ergometer and either stopped cycling or cycled at low rpm against no resistance. The resistance on the ergometer was manually removed following sprints and was reapplied by the Monark software when participants cycled at 100 rpm. Total peak power, average power and work done were recorded continuously (Monark Anaerobic Test Software, Monark, Varberg, Sweden).

3.6 Data Analysis

All testing data was analysed utilising a repeated-measures analysis of variance (ANOVA) where the factor was time (pre1, pre2 and post). A repeated-measures ANOVA was chosen because there are three time points for each participant for a given independent variable (Field, 2009). Repeated measures ANOVA allows the effect of different treatments to be tested within the same sample group (Kim, 2015). In order for a repeated measures ANOVA to be reliable and valid, a homogeneity of variance between each time point is assumed (Armstrong, 2017). Lack of homogeneity or sphericity increases the likelihood of an inaccurate conclusion being accepted; in particular a type I error (Armstrong, 2017). Sphericity was determined utilising Mauchly's test of Sphericity, with an insignificant result ($\varepsilon > 0.05$) indicating the assumption of homogeneity between samples cannot be made (Field, 2009).

When Mauchly's test of Sphericity was not significant, a Huynh-Feldt correction was applied. Huynh-Feldt correction is one of two corrections that should be applied to within subjects data (Kim, 2015). A paired-samples t-test was used to total peak power, average power and work done in HIIT session 1 and HIIT session 16. The level of significance was defined as $p \leq 0.05$. All data is presented as mean ± standard deviation (SD).

Cohen's effect size was determined as small ($d = 0.2$), medium ($d = 0.5$) or large ($d = 0.8$) (Cohen, 1988).

4. Results

4.1 Blood Pressure

There was no significant main effect for time for systolic blood pressure (p=0.942, d=0.29), diastolic blood pressure (p=0.675, d=0.09), resting heart rate (p=0.86, d=-0.10), pulse pressure (p=0.379, d=0.09) or aortic pulse wave velocity (p=0.385, d=0.34).

Table 4: Blood Pressure Analysis

	pre1	pre2	post
Systolic Blood Pressure (mmHg)	131 ± 10	130 ± 10	132 ± 15
Diastolic Blood Pressure (mmHg)	88 ± 12	87 ± 10	87 ± 13
Resting Heart Rate (bpm)	68 ± 10	68 ± 10	67 ± 7
Pulse Pressure (mmHg)	43 ± 11	44 ± 12	46 ± 13
Aortic Pulse Wave Velocity (m s^{-1})	10.5 ± 2.0	10.0 ± 1.4	10.1 ± 1.1

4.2 Critical Power

There was no significant main effect for time (Figure 1, p=0.17, d=-0.02).

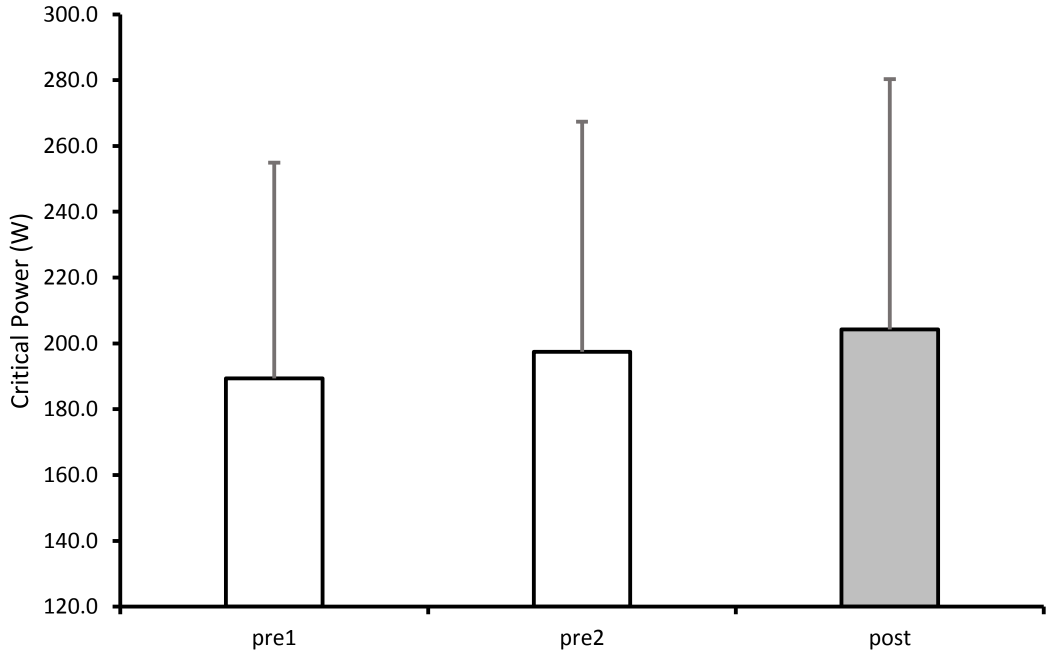

Figure 1: Change in Critical Power following HIIT.

4.3 VO_{2peak}

There was a significant main effect for time (p=0.004). Following 16 sessions of HIIT, VO_{2peak} was significantly increased compared to pre1 and pre2 (Figure 3; $p \leq 0.05$) with a large effect between control and post HIIT (d=1.16).

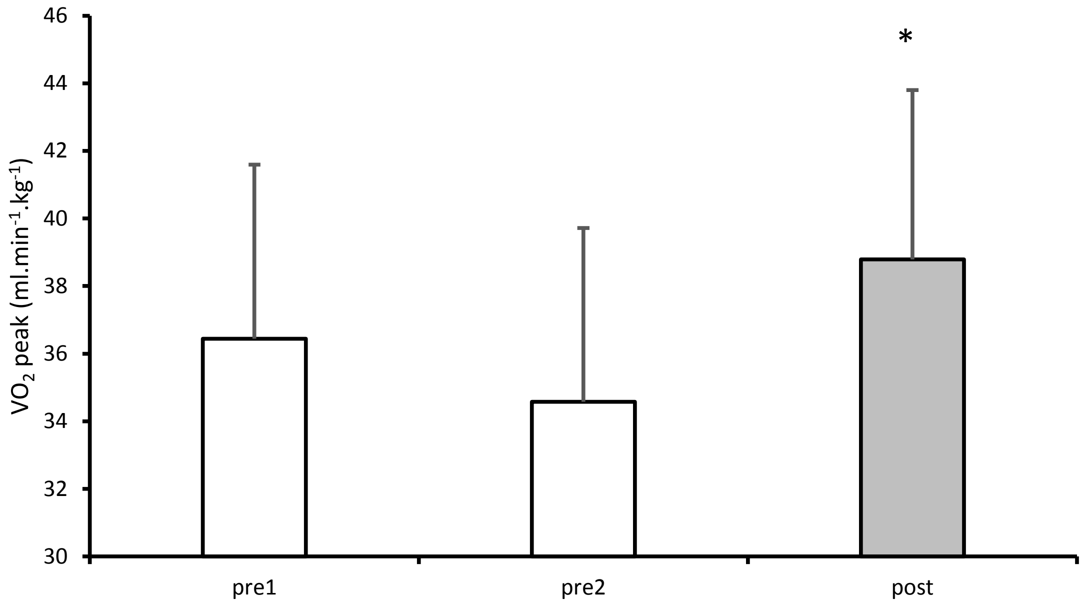

Figure 2: Changes in VO2peak following HIIT.

*$p \leq 0.05$ post compared to pre1 and post compared to pre2.

4.4 Time to Exhaustion

There was no significant main effect for time (p=0.12, d=0.27) although there was a trend for an 8 ± 10% improvement in time to exhaustion (Figure 4).

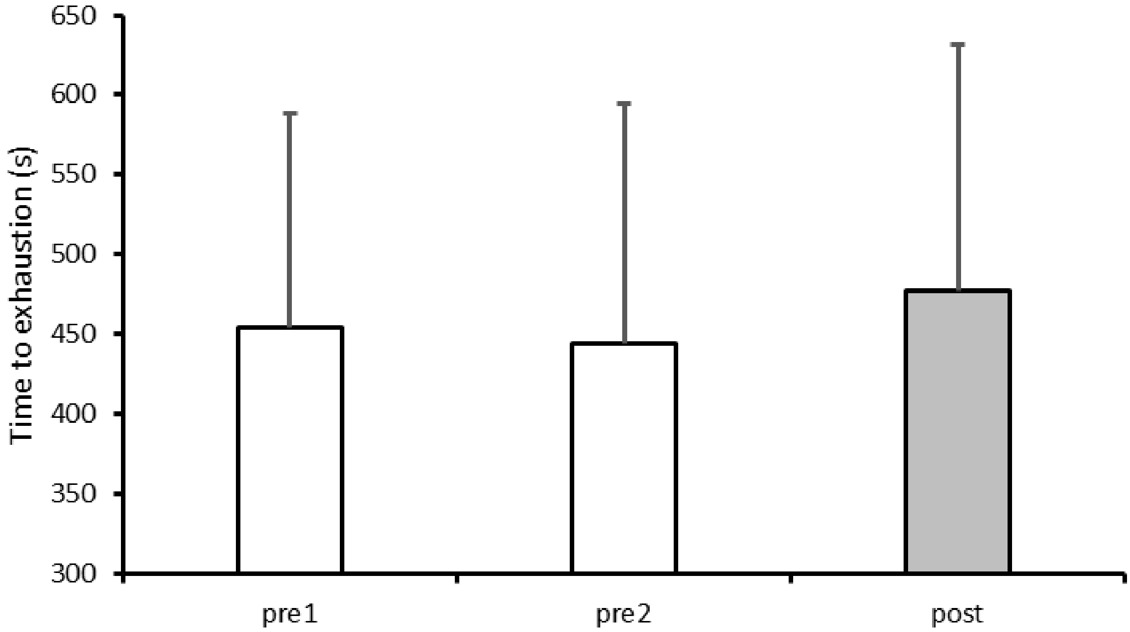

Figure 3: Change in time to exhaustion with HIIT.

4.5 Power and Work Done

Following 16 sessions of HIIT the total peak power, average power and work done across all sprints in the training session was significantly improved (Figure 5).

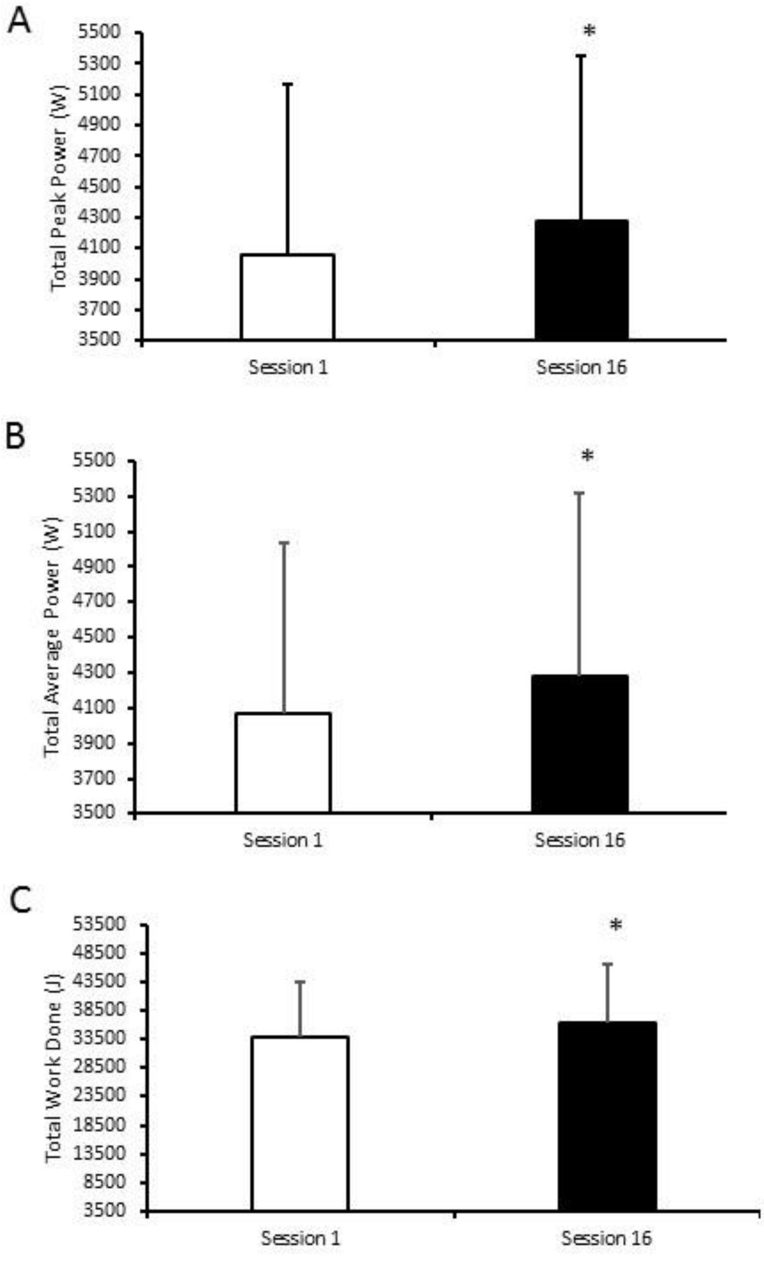

Figure 4: Changes in power and work across all sprints.

A: Total peak power, *p=0.01, d=0.20 session 1 compared to session 16; B: Total average power, *p=0.01, d=0.21 session 1 compared to session 16; C: Total work done, *p=0.01, d=0.22 session 1 compared to session 16.

5. Discussion

The aim of the present study was to determine if extremely short duration High Intensity Training is an effective method for Police Officers to maintain or improve their cardiovascular fitness. It was hypothesised that 8 weeks of High Intensity Interval Training would result in positive physiological and psychological adaptations in comparison to the control period; thus determining if Police Officers can effectively maintain or improve their cardiovascular fitness using HIIT. The present study found that HIIT significantly improves VO_{2peak}, personal happiness and total peak power, average power and work done across all sprints in the training session. There was no significant effect on subject's blood pressure, critical power, digit span testing, or time to exhaustion results however there was a trend for an 8 ± 10% improvement in time to exhaustion. These results imply that HIIT can improve cardiovascular fitness in Police Officers.

5.1 Blood Pressure

There was no significant main effect for time for systolic BP, diastolic BP, resting heart rate (HRT), pulse pressure (PP) or aortic pulse wave velocity (PWVao). Research has demonstrated that the effect of HIIT on blood pressure varies with level of hypertension in participants (Whyte, Gill & Cathcart, 2010). This was reaffirmed by Nyberg et al (2012) who discovered that 8 weeks of HIIT significantly reduced systolic (8.8 mm Hg) and diastolic BP (12.1 mm Hg) in hypertensive participants but not normotensive participants. The participants within the present study had an average BP of 131 ± 10 / 88 ± 12 mmHg defining the participants are normotensive. This is in agreement with Whyte, Gill & Cathcart (2010) who found no significant difference in systolic and diastolic BP or pulse wave velocity (PWV) in normotensive participants following 2 weeks of HIIT. In studies utilising only normotensive participants, Nybo et al (2010) found that 12 weeks of HIIT significantly reduced systolic BP by 8 mmHg. 12 weeks of HIIT demonstrated significant reductions in diastolic BP but not systolic BP by Schjerve et al (2008). This research identifies the benefits of 12 weeks of HIIT and implies that future studies should seek to replicate the present study with longer control and HIIT periods for normotensive

Police Officers.

Police Officers’ health is significantly impacted by participation in shift work (Wirtz & Nachreiner, 2012). As shift workers, Police Officers have a 40% increased risk of CVD due to variances in circadian rhythm, reductions in physical activity, stress and social patterns (Bøggild & Knutsson, 1999). Hypertension is the most prominent determinant of CVD and is the risk factor most likely to cause death (Kokubo, 2014). Hypertension is predicted to affect 1.56 billion people by 2025 (Kearney et al. 2005). Hypertension is identified by having systolic and/ or diastolic BP over 140 mmHg and 90 mmHg respectively (Molmen-Hansen et al. 2011). For Police Officers with hypertension, work situations that require vigorous physical activity such as Critical Incidents can lead to CVD events taking place whilst on duty (Kales et al. 2009). This can be induced from the transition between the predominantly sedentary aspects of the role quickly changing into high intensity Critical Incidents (Kales et al. 2009). CVD events account for 22% of all on duty deaths for Police Officers but typically only 10-15% of on duty deaths for occupations out with of the emergency services (Kales et al. 2009).

Research by Molmen-Hansen et al (2011) found that 12 weeks of HIIT significantly reduced systolic (12 mmHg) and diastolic 24 hour ABP (8 mmHg) in participants with hypertension. Tjønna et al (2008) found that 16 weeks of HIIT significantly reduced systolic (10 mmHg) and diastolic BP (6 mmHg). These participants were recruited for metabolic disorders but had average BP of 144 ± 5 / 95 ± 3; classifying participants as hypertensive (Tjønna et al. 2008). Whilst the participants who volunteered to take part in the present study were normotensive, HIIT could prove useful for their hypertensive colleagues within the police force.

5.2 Critical Power

There was no significant effect for time for CP. There was a 2.5 ± 8% increase in CP post HIIT in compared with pre2. CP is defined as the maximal rate of muscular work at which constant rate exercise can be sustained (Constantini, Sabapathy & Cross, 2014). Dependent on the individual, CP equates to 70-90% of VO_{2peak} and this constant rate exercise highlights the highest lactate state and oxidative work that the body can maintain (Jones & Vanhatalo, 2017). Following this, the body is inefficient at clearing hydrogen ions (H^+) and the individual will experience fatigue (Kendall et al. 2009). The limited amount of exercise that the body can complete above CP is recognised as *W´* (Vanhatalo, Doust & Burnley, 2007).

Very few studies have demonstrated the relationship between HIIT and CP (Kendall et al. 2009). Kendall et al (2009) found that individuals participating in HIIT training only had no increase in CP following 5 or 6 2 minute sprints at 80 – 120% VO_{2peak} with 1 minute rest in between; but did not measure final VO_{2peak}. This equated to a work:rest ratio of 1:2. Yamagishi & Babraj (2017) measured the effect of HIIT on CP and found a significant increase in CP following 6 15 second sprints with 2 minutes recovery between sprints. This study showed an significant increase in VO_{2peak} alongside CP whilst using a work:rest ratio of 1:8.

The choice of sprint duration was based on Kavaliauskas, Aspe & Babraj (2015) who found that 6 10 second sprints with 30 seconds rest significantly improved aerobic performance measured using self-paced 3km time trial and time to exhaustion but did not significantly improve anaerobic performance on 30 second Wingate test. The use of CP is traditionally based on applications to endurance exercise; however recovery of *W´* in HIIT is not linear and is slower in repeated bouts of HIIT (Jones & Vanhatalo, 2017). With 6 10 seconds sprints with 30 second rest periods, the researchers hypothesised that shorter rest periods had a negative impact on power production and *W’* in succeeding sprints (Kavaliauskas, Aspe & Babraj (2015). However Skiba et al (2014) argues that muscle perfusion may be higher with shorter recovery times, meaning that muscles access more oxygen, fatigue metabolites such as H^+ are removed faster and *W’* regenerates faster. Further research is required to determine the most effective protocol for increasing CP utilising HIIT with considerations for work:rest ratio and sprint time (Skiba et al. 2014).

5.3 VO_{2peak}

VO_{2peak} is an indicator of the body's ability to transport oxygen during exercise and highlights an individual's level of cardiorespiratory fitness and performance in endurance exercise (Hawkins et al. 2007). Aerobic capacity and endurance are well evidenced as essential to the role of a police officer in dealing with Critical Incidents whilst wearing SRBA (Crawley et al. 2015, Bonneau & Brown, 1995; Shephard & Bonneau, 2002; Collingwood, Hoffman & Smith, 2004; DiVencenzo et al. 2014). Cardiovascular fitness can counteract the detrimental effects that shift work has on police officer health (Wirtz & Nachreiner, 2012).

The present study found a significant increase in VO_{2peak} following HIIT in comparison with pre1 and pre2, with a large effect size. There was a 13 ± 13% increase in VO_{2peak} between pre2 and post. The present HIIT protocol is effective at increasing VO_{2peak} in front line, operational police officers. This builds on research by Kavaliauskas, Aspe & Babraj (2015) who found that the protocol used in the present study did not significantly increase VO_{2peak} following 6 sessions over 2 weeks. This implies that 6 10 second sprints with 30 seconds recovery is an effective protocol at increasing VO_{2peak} when 16 sessions are conducted over 8 weeks. Whilst many different HIIT protocols can increase VO_{2peak}, the benefit of this protocol is its time efficiency. One of the most researched HIIT protocols to increase VO_{2peak}, Wingate based HIIT requires approximately 20 minutes (Gibala et al. 2012). Time is the most frequently cited barrier for participation and shift workers such as police officers find it especially difficult to find time to exercise (Gibala et al. 2012; Harrington, 2001). With a 2 minute warm up, 2 minute cool down, sprints and recovery periods, this HIIT protocol would require participants to remain on a cycle ergometer for 7.5 minutes.

It is well documented that HIIT is a time efficient method by which aerobic capacity can be significantly increased (Burgomaster et al. 2008; Nybo et al. 2010; Gibala et al. 2012; Schjerve et al. 2008). HIIT works by activating PGC-1α which in turn increases mitochondrial biogenesis (Gibala et al. 2012). Mitochondrial biogenesis is where cells with mitochondria grow or increase in quantity, allowing cells to create more ATP (Russell et al. 2014). Increase in mitochondria within skeletal muscle cells enables the oxidative capacity of the cells to increase, sustaining endurance exercise for longer periods of time (Gibala & McGee, 2008).

5.4 Time to Exhaustion

Time to exhaustion can gauge changes in performance during endurance exercise (Amann, Hopkins & Marcora, 2008). Burgomaster et al (2005) found that 2 weeks of wingate based HIIT increased time to exhaustion by 100%; measured during exercise completed at 80% VO_{2peak}. This test is representative of exercise at which energy is predominantly generated aerobically; implying increases in time to exhaustion are associated with increases in endurance capacity (Burgomaster et al. 2005).

The present study did not find a significant increase in time to exhaustion however there was a trend for an 8 ± 10% improvement in time to exhaustion. The present study used an incremental exercise test, which demonstrated an increase in VO_{2peak}. It has been suggested that significant increases in VO_{2peak} but no significant increase in time to exhaustion can be attributed to incremental exercise test used (Mendes et al. 2013). As the resistance on the cycle ergometer increased with time, it is suggested that the main determinant of time to exhaustion was associated with the level of power output required at that point, as opposed to fatigue (Mendes et al. 2013). A constant intensity test using a percentage of VO_{2peak}, may provide more accurate time to exhaustion readings (Currell & Jeukendrup, 2008).

5.5 Power and Work Done

The present study identified total peak power, average power and work done across all sprints in the training session was significantly improved in session 16 in comparison with session 1. This supports research by MacDougall et al (1998) who found that 3 sessions of HIIT per week for 7 weeks significantly increased peak power and total work. MacDougall et al (1998) used four 30 second sprints with 4 minutes rest at 7.5% of subject's body mass. Jakeman, Adamson & Babraj (2012) found 6 HIIT sessions over 2 weeks significantly increased peak power during HIIT. This protocol consisted of 10 6 second sprints at 7.5% body mass with 60 seconds rest in between (Jakeman, Adamson & Babraj, 2012).

ATP production during high intensity sprints <10s is primarily sourced by glycogenolysis, where glycogen is broken down into glucose (Gaitanos et al. 1993). Following maximal exercise, skeletal muscle supercompensates by storing higher levels of glycogen (Roedde et al. 1986). This effect has been demonstrated in HIIT with wingate based HIIT proven to increase resting skeletal muscle glycogen stores (Burgomaster et al. 2005). It has been suggested that increased glycogen stores are the reason behind adaptations to power output following HIIT (Jakeman, Adamson & Babraj, 2012). As the present study utilised 10 seconds sprints, this suggests that increases in total peak power, average power and work done can be attributed to increased skeletal muscle glycogen stores. As skeletal muscle glycogen was not measured in the present study, this can only be hypothesised.

5.6 Practical Implications

A HIIIT protocol consisting of 6 10 second sprints against 6.5% or 7.5% of body mass; with 30 seconds rest in between improves VO_{2peak}. This could be of benefit to both Police Officers and members of the general public who are seeking the most time efficient means possible of exercising (Booth et al. 2000). The benefit of such an exercise intervention for Police Officers is the small maximal exercise time and the nature of weight supported exercise; reducing the likelihood of injury (Jakeman, Adamson & Babraj, 2009). As there was no significant difference between physiological testing parameters following the control period, this implies that Police Officers need supervision and guidance in order to maintain their fitness (Rossomanno et al. 2012). The present HIIT protocol enables Police Officers to increase their fitness for duty and hence, their occupational effectiveness.

5.7 Limitations

Time to exhaustion was measured during an incremental exercise test alongside VO_{2peak}. Whilst this provided valid and reliable readings for VO_{2peak}, some researchers have suggested that time to exhaustion during incremental tests could be skewed by increases in incline or resistance (Mendes et al. 2013). This may explain why VO_{2peak} had significant increases but time to exhaustion did not, despite the fact that they are both indicators of aerobic fitness. If time to exhaustion is to be a key indicator of aerobic capacity, constant intensity exercise testing protocols may provide more valid results (Amann, Hopkins & Marcora, 2008). Alternatively, Currell & Jeukendrup (2008) have suggested that self-paced time trials are more reliable measures of aerobic capacity with lower variation in results. Self-paced time trial would provide more ecologically valid results, whereby Police Officer's ability to chase suspects across a given distance could be measured (Currell & Jeukendrup, 2008). Testing protocols more applicable to the unique role of a police officer can better measure the impact of specific training interventions on occupational performance (Rossomanno et al. 2012).

This study conducted physiological testing at the same time on each occasion in order to reduce the effects of circadian rhythm on exercise performance (Constantini & Hackney, 2013). For Police Officers, this may not ensure a consistent representation of circadian rhythms due to rotating shift patterns experienced by the participants (Harrington, 2001). In order to remove the influence of circadian rhythms on exercise physiology, an alternative would be to test Police Officers on a consistent phase of their shift pattern. That being said, the reality of a Police Officer's role is to meet the physiological demands of the job at any point during their shift pattern (Anderson, Plecas & Segger, 2001). The present study could be considered as ecologically valid and a true reflection of the realities of shift work for Police Officers.

The sample size of this study was small, with smaller sample sizes having reduced validity in significant results (Faber & Fonseca, 2014). This reduces the ability to apply results to real world settings (Hojat & Xu, 2004). The present study does however increase knowledge regarding HIIT for Police Officers and indicate that further research would be beneficial (Arena et al. 2013).

5.8 Future Recommendations

Given that HIIT has been shown to reduce BP readings in hypertensive participants and that Police Officers have an increased risk of CVD, future research should look to measure the effect of HIIT in Police Officers with hypertension (Nyberg et al. 2012; Bøggild & Knutsson, 1999). The average blood pressure reading for the sample highlighted the participants as predominantly normotensive. De Souto Barreto, Ferrandez & Saliba-Serre (2013) found that in the over 60s, participants who volunteer for exercise studies tend to be in better health and more physically active than those who do not. It could be argued that this effect existed within the present study, with those who are more physically active and therefore those in better cardiovascular health volunteering to take part than their less physically active colleagues.

One of the perceived benefits of HIIT for Police Officers is the time efficiency for a population who find it difficult to find time to exercise (Gibala et al. 2012; Harrington, 2001). Whilst HIIT is a shorter protocol, it requires a substantial effort in order to elicit physiological adaptations which may not be welcomed by some members of the public (Gibala & McGee, 2008). Given the unpleasant nature of maximal exercise such as HIIT, future research should explore the compliance of participants using HIIT is less clinical settings (Arena et al. 2013). Rossomanno et al (2012) found that Police Officers required supervision in order to ensure compliance in a prescribed exercise protocol.

Future studies should look to explore the long term benefits of HIIT for Police Officers in order to determine the longevity of physiological adaptations to HIIT (Gibala et al. 2012). Whilst certain mechanisms have been found to elicit changes equal to that of ET, more research is required to determine a complete comparison of HIIT and ET (Burgomaster et al. 2008). 12 weeks of HIIT was found to have no significant impact on muscle or bone mass on participants (Nybo et al. 2012).

6. Conclusion

This study demonstrated that HIIT is a time efficient method for Police Officers to maintain or increase their cardiovascular fitness. This study explored the benefit of 6 10 second sprints with 30 seconds recovery in between against 7.5% or 6.5% of subject's body mass. 8 weeks of HIIT consisting with two training sessions a week, increases VO_{2peak} by 13 ± 13%. Cardiovascular fitness is an integral part of both occupational fitness and health maintenance for Police Officers. With task analysis showing the role of a Police Officer is similar across Europe, Australia, America and Canada, this research could have implications wider than that of Scotland.

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Appendices

Appendix A – Study Advertisement

FRONT LINE OPERATIONAL POLICE OFFICERS WANTED (GENERAL BEAT DUTIES & CID)

We require front line, operational police officers to take part in a study looking at whether twice weekly High Intensity Training (HIT) will improve cardiovascular fitness. HIT has been shown to be beneficial for health and fitness and we previously saw that HIT improves multi stage fitness test performance in police officers.

The study involves 3 fitness testing days over 16 weeks, with each session lasting a maximum of 2 hours. After the second fitness test you will be asked to take part in 8 weeks of twice weekly HIT with each training session lasting 6 minutes. The study is free and times will be flexible around shift patterns and family commitments.

To take part you must not currently taking part in high intensity exercise and not sustained any lower leg injuries in the last 6 months.

For further information please contact Jennifer Scally: email –
[redacted]
(Supervisor Dr John Babraj [redacted])

Appendix B – Participant Information Sheet

PARTICIPANT INFORMATION SHEET

Research Title: High Intensity Training on the Cardiovascular Fitness of Front Line Police Officers

Research Aim:

The aim of this study is to find out if High Intensity Training is a good way of maintaining or improving your cardiovascular fitness.

PART 1

1. Invitation

You have been invited to take part because you are a front line operational police officer. You are also aged 18 years old or over, do not currently take part in High Intensity exercise (such as circuits), are fit to exercise and have not experienced a lower leg injury in the past 6 months.

Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information sheet carefully, and discuss it with others if you wish. Feel free to ask if there is anything that is unclear, or if you would like more information. You are more than welcome to take time before deciding whether or not to take part.

2. **What is the purpose of the study?**

The aim of the study is to find out whether or not High Intensity Training can help police officers maintain and/or improve their cardiovascular fitness. High Intensity Training takes considerably less time than most endurance exercise and so could be preferable as it is less time consuming.

3. Do I have to take part?

No. It is entirely up to you if you would like to take part in the study. If you decide that you would like to be a part of the study, then you will be asked to sign an informed consent form. The informed consent form confirms that you're happy to take part in the study and that you understand what the study involves. Even after you have signed the informed consent form, you are free to leave the study at any point, without giving a reason.

4. What will happen to me if I take part?

If you decide to take part, you will then be asked to attend a testing day where you will be asked to complete a questionnaire about your readiness to exercise. After this, you'll be asked to fill in a participant information form about the physical activity you do and any recent injuries. Your weight will also be recorded in order to determine the resistance that will be on the exercise bike for your High Intensity Training.

Your blood pressure will then be measured over half an hour. You will be required to stay within the university at this time and during this period, you will be asked to complete a questionnaire about your personal happiness and some cognitive tests.

After this, you will be asked to take part in an exercise test on a treadmill in order to measure your cardiovascular fitness. The speed of the treadmill and/or the steepness of the treadmill will be increased over time. You are asked to keep jogging on the treadmill until you feel you are no longer able to do so. This is called a graded exercise test.

On another day in the same week, you will be asked to complete a different fitness test on an exercise bike. This will involve cycling on the bike for 3 minutes before cycling for 3 minutes against a resistance. This is called a critical power test.

Then, you will be asked to take part in a control period where you continue to exercise as you normally do. This period lasts 8 weeks.

Having completed the control period, you will be asked to attend another testing day. This testing day will be the same as the one completed at the beginning of the study, where your blood pressure, happiness questionnaire and cognitive tests are repeated. After this you will be asked to complete another graded exercise test and critical power test.

You are then required to complete the High Intensity Training program for 8 weeks. This comprises of sessions twice a week; with each session lasting approximately 15 minutes. Efforts will be made in order to ensure that a convenient time is arranged for each participant.

In order to warm up for the training program, you will be asked to complete 2 minutes of unweighted cycling beforehand.

The High Intensity Training program involves 6 all out sprints on a bike; each lasting 10 seconds. A resistance (weight) will be placed on the bike based on your own weight and there is 30 seconds rest between each sprint.

You will then be asked to complete a final testing day where blood pressure is measured and you will be asked to complete the same happiness questionnaire and cognitive tests. After this you will be asked to complete a graded exercise test and a critical power test – as completed previously.

The study itself lasts about 19 weeks in total. The control period requires no additional effort and the High Intensity Training program takes 30 minutes a week (split into two 15 minute sessions). There are 3 testing weeks, each lasting about 2 hours.

Your results will be kept private and no individual results will be reported at any time. Police Scotland may be informed of the average results of the participants but no individual results will be passed on and all participants will remain anonymous. You will not be informed of any of the results until the end of the entire study. If you choose to leave the study at any point, you will be provided with your results if you so wish.

I will keep a record of your results on Microsoft Excel. This sheet will be password protected and individuals will remain anonymous. For example, in these results you might be referred to as Participant A – never by your name.

5. What are the possible risks of taking part?
A risk assessment has been conducted and approved by Abertay University's ethics committee. The main risks are due to the extra strain placed on your body from the maximal sprints and the impact this will have on your body in terms of the strain on your heart and muscles. In order to ensure your safety, you will asked to complete questionnaires on your readiness to exercise and relevant medical history.

6. What happens when the research study stops?
At the end of the study you will be given the option of seeing your results. If you choose to leave the study, you will also be given this option.

Your results will be added to the rest of the participants – no individual results will be passed on. As a group, the results may be relayed back to other people, including Abertay University and Police Scotland. I will never inform others of individual results or allow your results to be identifiable as yours.

7. What if there is a problem?
If you have any questions or concerns, please feel free to ask and the researcher will do their best to answer the question.

This completes Part 1 of the Information Sheet. If the information in Part 1 has interested you and you are considering participation, please continue to read the additional information in Part 2 before making any decision.
PART 2

8. What will happen if I don't want to carry on with the study?
You are free to leave the study at any point, without giving a reason.

9. Will my part in this study be kept confidential?
Your results will be kept private and no individual results will be reported at any time. Police Scotland may be informed of the average results of the participants but **no**

individual results will be passed on and all participants will remain anonymous. The results will be kept on a password protected computer for 5 years in order to comply with regulations.

10. What will happen to the results of this study?

The results of the study will be available after it is completed. All results will be anonymous and you will not be identified in any results. They may be published in a scientific journal or presented at a scientific conference. If you would like to see the results of the study, or the publication, please let the researcher know and you will be provided with them.

11. Who is organising and funding this study?

This study is organized and funded by Abertay University.

12. Contact for further information

Please feel free to take this information sheet away with you and take as long as you like to decide if you would like to take part in the study. If you have any questions, please feel free contact the researcher and every attempt will be made to respond to your queries promptly.

My email address is [redacted] . My supervisor, Dr John Babraj can be contacted at [redacted] .

This project has been reviewed and approved by the Research Ethics Committee of the School of Social and Health Science

Appendix C – Informed Consent Form

INFORMED CONSENT FORM

Research Title: Extremely Short Duration High Intensity Training as a Cardiovascular Training Method for Front Line Police Officers

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that the University of Abertay Dundee has approved all procedures.

- I have read and understood all information provided and this consent form.
- I have had the opportunity to consider the information, ask questions about my participation and have had these answered satisfactorily.
- I understand that I am under no obligation to take part in the study.
- I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.
- I understand that my information will be used for reporting purposes but I will not be identified.
- I understand that my information will be kept securely for a period of 5 years because you are required to do so by the university.
- I agree to participate in this study.

YOUR NAME ______________________________________

YOUR SIGNATURE ______________________________________

DATE ______________________________________

RESEARCHER'S SIGNATURE ______________________________________

Appendix D – Participant Information Form

PARTICIPANT INFORMATION FORM

Research Title: Extremely Short Duration High Intensity Training as a Cardiovascular Training Method for Front Line Police Officers

All information is private and confidential.

It is asked that you answer as honestly and truthfully as possible in order to ensure your welfare throughout the study.

Full Name	
Date of Birth (DD/MM/YYYY)	
Contact Telephone Number	
Gender	

Emergency Contact	
Name	
Contact Telephone Number	

Within the past 6 months, have you suffered any injuries? If so, please explain below.

Are you currently involved in any regular fitness programmes, sports or exercise? If so, please explain below.

Are you involved in any High Intensity exercise? E.g. circuit training. If so, please explain below.

Do you complete any other physical activity not mentioned above? If so, please explain below.

Appendix E – Physical Activity Readiness Questionnaire

Abertay University

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Research Title: Extremely Short Duration High Intensity Training as a Cardiovascular Training Method for Front Line Police Officers

All information is private and confidential.

It is asked that you answer as honestly and truthfully as possible in order to ensure your welfare.

	YES	NO
Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?		
Do you feel pain in your chest when you do physical activity?		
In the past month, have you had chest pain when you were not doing physical activity?		
Do you lose your balance because of dizziness or do you ever lose consciousness?		
Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?		

	YES	NO
Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?		
Do you know of <u>any other reason</u> why you should not do physical activity?		

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, please inform the researcher before any further physical activity.

I have read, understood and completed this questionnaire to the best of my knowledge.

YOUR NAME ____________________________________

YOUR SIGNATURE ____________________________________

DATE ____________________________________

RESEARCHER'S SIGNATURE ____________________________________